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TITLE: ANTARES ALIGNMENT GIMBAL POSITIONER

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Antares alignment gimbal positioner

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Abstract

Antares is a 24-beam 40-TW carbon-dioxide (CO_2) laser fusion system currently under construction at the Los Alamos National Laboratory. The Antares alignment gimbal positioner (AGP) is an optomechanical instrument that will be used for target alignment and alignment of the 24 laser beams, as well as beam quality assessments. The AGP will be capable of providing pointing, focusing, and wavefront optical path difference, as well as aberration information at both helium-neon (He-Ne) and CO_2 wavelengths. It is designed to allow the laser beams to be aligned to any position within a 1-cm cube to a tolerance of 10 μm.

Introduction

The Antares inertial confinement fusion system will focus 24 laser beams onto a tiny target (typically 500 μm in diameter) located approximately at the center of a 7.3-m-diam by 7.3-m-long vacuum (10^{-6} torr) chamber. It is desirable to be able to focus each laser independently anywhere within a 1-cm cubic volume surrounding the target center. To accomplish the target alignment task, it was decided to build an instrument that would (1) hold a variety of detectors; (2) point a detector at each laser beam to within ±0.5° of the desired angle; (3) translate the detector ±5 mm from a reference location in the x, y, and z axes; and (4) know the detector position relative to the reference throughout the travel of each motion to within 10 μm.

Smartt interferometer detector description

The optical design presented in this paper is based on the use of the Smartt interferometer as the detector. The use of Smartt interferograms for alignment of laser systems has been described previously.[1] Another article in these proceedings[2] describes optical analysis using Smartt fringes near focus. Figure 1 shows the types of fringes used for determining correct focus and pointing positions for the laser beam. Briefly, the focus position is determined by the change in curvature of the fringes (as seen in the left column of fringes in Fig. 1) as the Smartt fringes are observed in separate planes, including the correct focal plane. Simultaneously, the correct pointing is obtained by observing the change of slope across the image plane (the middle and right columns of fringes in Fig. 1). The ideal focus and pointing positions are the middle row positions in Fig. 1. Figure 2 shows the type of fringes used for optical analysis. These fringes are digitized and the program FRINGE[3] is used for the optical analysis. The FRINGE program fits the data to a Zerinke polynominal set and thus computes the various optical parameters of interest, such as third order aberration contributions, Strehl Ratio, and encircled energy distributions.

AGP detail description

Mechanical design

To satisfy the mechanical requirements, an AGP is being designed that basically consists of a gimbal mounted to an x, y, z micropositioner, which holds and points the detector. A line drawing of the AGP is shown in Fig. 3.

Gimbal description. Each gimbal axis is defined by two preloaded ultra-precision ball bearings. The detector center is precisely located at the intersection of these two axes, thus allowing the detector to be pointed anywhere in space without translation from the axes intersection. The gimbal axes are rotated independently by two gear head-stepping motors that are specially designed to operate in a 10^{-6}-torr vacuum. Rotational feedback information is provided by two rotary optical encoders of the type shown in Fig. 4. The encoder resolution of 0.36° ±0.03° allows the pointing to be within the ±0.5° tolerance required. The encoders also have an index mark that can be used as a cross reference to determine that encoder pulses are not erroneously being added or subtracted.

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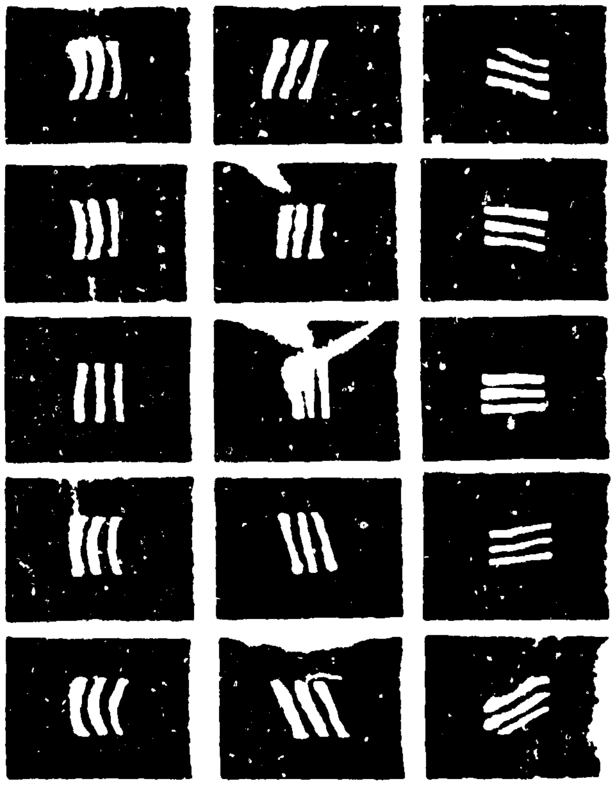


Figure 1. Focus and pointing fringes.

Figure 2. Optical analysis fringes.

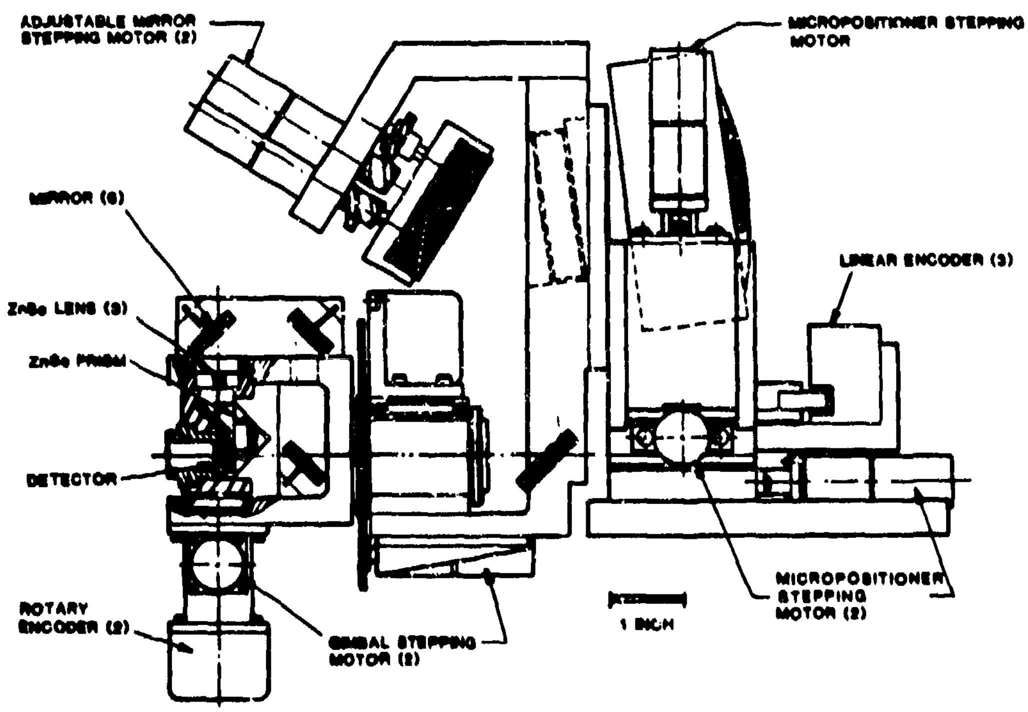
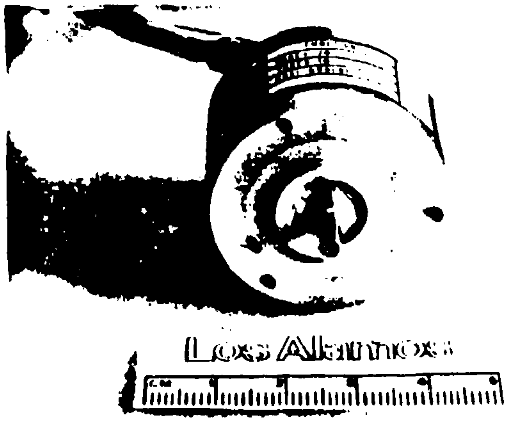


Figure 3. Antares AGP schematic.



F'gure 4. AGP rotary encoder.

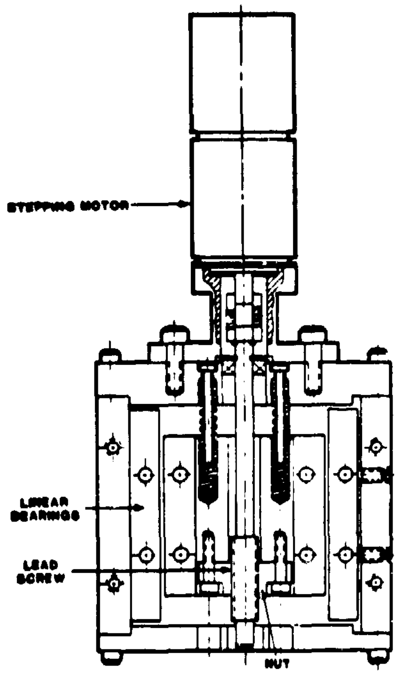


Figure 5. AGP micropositioner.

Micropositioner description. The gimbal is mounted to a bracket that is attached to three mutually orthogonal micropositioners. This allows translation of the detector in the x, y, and z axes. The micropositioner axes are defined by preloaded linear bearings. Axial movement is accomplished by a lead screw with ground threads. The grinding process provides a good surface finish, thus enabling a smooth linear movement. Figure 5 shows a cross section of the micropositioners. Special lubricants must be used to be compatible with the vacuum and the ultra-clean environment. We have decided to use HI-T-LUBE* on the lead screws and NEDOX* on the nut and linear bearings. These lubricants consist of a thin electro-deposited coating that accepts a controlled infusion of fluorocarbon. This process causes the lubricated surface to become very hard and wear resistant, and also to have a very low coefficient of friction. The micropositioners are driven by vacuum-compatible stepping motors. The position is monitored by linear optical encoders mounted to each micropositioner. The resolution of the encoders is 1.0 μm ±0.3 μm. An index pulse is also supplied with the linear encoders, which will be used to determine that the encoders are operating properly. Figure 6 is a photograph of the linear encoders.

Error budget

An error budget, shown in Table 1, has been determined for the major interfaces of the AGP.

Table 1. AGP Error Budget

1. Gimbal axes intersections	2.5 μm
2. Gimbal axes runout	2.5 μm
3. Detector mislocation	5.0 μm
4. Detector replacement[a]	1.0 μm
5. x, y, z axes orthogonality	2.5 μm x 3
6. x, y, z axes ABBE offset error	2.5 μm x 3
Total RSS Error	8.7 μm

[a]The detector replacement error refers to the positional error introduced when one detector is substituted in the gimbal for another detector.

*Trade names of coatings from General Magnaplate Corporation, 1331 US Route No. 1, Linden, NJ 07036.

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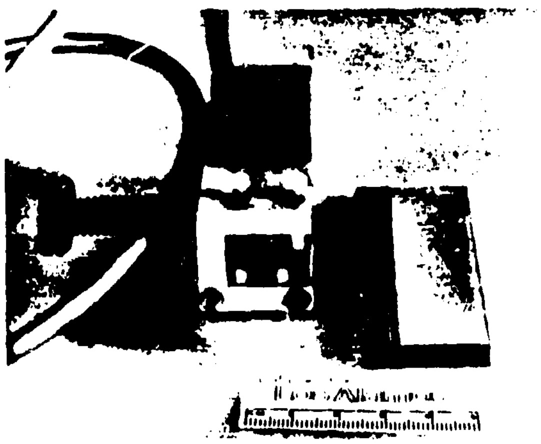

Figure 6. AGP linear encoder.

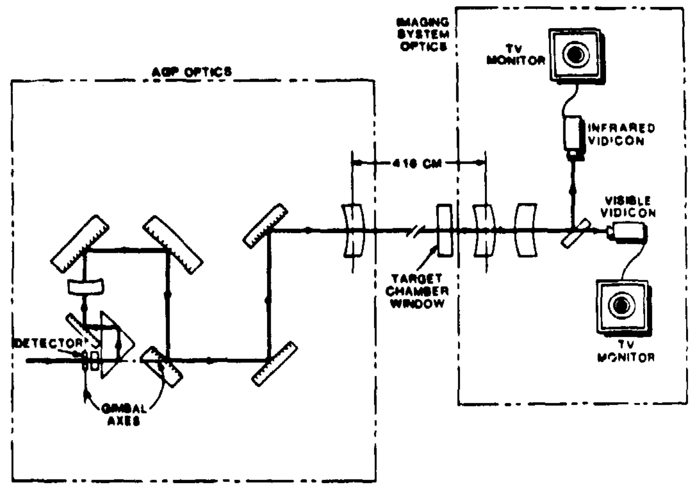

Figure 7. AGP Smartt interferometer detector optical layout.

Controls

The stepping-motor drivers and the encoders will be operated with the aid of a computer-based control system. All five axes can be driven simultaneously, so the maximum time required to go from one position to another will be 50 s.

Optical design of the AGP

The original optical design proposed by one of the authors[4] had to be radically altered because the design had large amounts of zinc-selenide, which made the manufacturing tolerances very tight, and also because we were unable to cement zinc-selenide prisms so that both He-Ne and CO_2 light could be successfully transmitted through the cement. The current design, shown schematically in Fig. 7, contains only one zinc-selenide prism, and the system is corrected for both He-Ne and CO_2 wavelengths; the only change is that different vidicon locations are required to correspond to the respective image planes for the two wavelengths. Table 2 gives the prescription for the optical design. We have experimentally demonstrated that Smartt fringes in both He-Ne and CO_2 wavelengths can be relayed over the large distances involved in the Antares system. The optical design was optimized using the routines available in ACCOS V and the level of correction is $\lambda/2$ peak-to-peak in both He-Ne and CO_2 wavelengths. This is quite adequate for a relay system of this type as the aim is just to transfer the Smartt fringes to a more convenient location.

Alignment procedure

The method used to align the laser to the target is as follows.

(1) Insert a surrogate target into the target chamber that is located by a kinematic mount.
(2) Align two orthogonal telescopes to the surrogate target center.
(3) Retract the surrogate target and insert the AGP (which also rests on a kinematic mount).
(4) Point the detector center at each telescope and adjust the position until the detector center is coincident with the focal point of both telescopes.
(5) Record the linear and angular positions.
(6) Translate and point the detector to the desired laser beam focus position.
(7) Use the detector information to align the desired laser beams.
(8) Return to the reference position to determine that no positional errors have been introduced.
(9) Repeat steps 6 through 8 as often as required.
(10) Retract the AGP and insert the target.
(11) Align the target center to the telescopes' focal points.

Now, the laser beams and the target are aligned.

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Table 2. AGP Lens Prescription

Smartt Relay System Basic Lens Data

Surface Number	Curvature	Thickness	Medium
0	0.000	66.643000	Air
1	0.000	0.062500	Air
2	0.011	0.156250	Zinc selenide
3	0.000	0.062500	Air
4	0.000	0.281250	Zinc selenide
5	0.000	0.000000	Reflection
6	0.000	-0.500000	Zinc selenide
7	0.000	0.000000	Reflection
8	0.000	0.281250	Zinc selenide
9	0.000	0.218750	Air
10	0.000	0.000000	Reflection
11	0.000	-0.343750	Air
12	0.196	-0.218750	Zinc selenide
13	0.654	-0.594250	Air
14	0.000	0.000000	Reflection
15	0.000	0.500000	Air
16	0.000	0.218750	Air
17	0.000	0.500000	Air
18	0.000	0.000000	Reflection
19	0.000	-0.250000	Air
20	0.000	-1.406250	Air
21	0.000	0.000000	Reflection
22	0.000	0.406250	Air
23	0.000	2.125000	Air
24	0.000	0.750000	Air
25	0.000	0.000000	Reflection
26	0.000	-3.437500	Air
27	0.000	0.000000	Reflection
28	0.000	6.500000	Air
29	-0.029	0.250000	Zinc selenide
30	-0.069	149.250000	Air
31	0.000	3.000000	Sodium chloride
32	0.000	12.000000	Air
33	-0.009	0.250000	Zinc selenide
34	-0.013	1.250000	Air
35	0.007	0.250000	Zinc selenide
36	0.002	172.335507	Air
37	0.000	-100.000000	Air
38	0.000	0.000000	Air

Tilt and Declination Data

Surface	Type	Alpha
5	Tilt	-45.0000
6	Tilt	-45.0000
7	Tilt	-45.0000
8	Tilt	-45.0000
10	Tilt	45.0000
11	Tilt	45.0000
14	Tilt	45.0000
15	Tilt	45.0000
18	Tilt	45.0000
19	Tilt	45.0000
21	Tilt	-45.0000
22	Tilt	-45.0000
25	Tilt	-37.5000
26	Tilt	-37.5000
27	Tilt	40.0000
28	Tilt	40.0000
37	Tilt	0.0000
38	Tilt	0.0000

Reference Object Height	Reference Aperture Height	Object Surface	Reference Surface
-0.779000E+01 (6.67°)	0.03900	0	1

Image Surface	Effective Focal Length	Back Focal Length	F/Number	Length	Magnification
38	-5.1660	-100.0000	-65.77	345.0855	0.076983

Wavelength Number	1	2
Wavelength	0.63280	10.60000

Aperture stop at Surface 1. Lens units are inches. Evaluation mode is focal.

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Schedule

The detail design of the micropositioners has been completed. The gimbal design is expected to be completed in the summer of 1981. Fabrication of the AGP is expected to begin in August 1981 and to be completed in November 1981. Testing of various linear bearing systems to determine the optimum configuration is expected to be completed in the spring of 1981. Testing of the entire assembly is expected to be completed by April 1982; then it will be incorporated into routine use in Antares.

Conclusions

The Antares AGP is expected to be a very versatile instrument that will enable the laser-target alignment to be performed with the necessary precision.

Acknowledgments

The detail design assistance of R. H. Spencer, D. D. Pierce, H. E. Tucker, and C. E. Cummings has been greatly appreciated.

References

1. Viswanathan, V. K. and Bolen, P. D., proceedings of the SPIE, Vol 179, p. 107 (1979).

2. Viswanathan, V. K., Bolen, P. D., Liberman, I., and Seery, B. D., proceedings of the LASL Conference on Optics '81, "Optical Analysis and Alignment Applications using the Infrared Smartt Interferometer."

3. FRINGE is an interferogram reduction program developed by J. Loomis while at Optical Sciences Center, University of Arizona.

4. Sweatt, W. C., "Alignment and Focusing Device for a Multibeam Laser System," proceedings of the SPIE 24th Annual Technical Symposium, San Diego, California, July 28-August 1, 1980.